

## First Report on Dung Profile of Banbakri Antelope: Ecological Insights for Sustainable Farming

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### Abstract

Dung from wild herbivores serves as an important source of organic matter and nutrients, enhancing soil fertility and promoting sustainable farming systems. However, information on the dung characteristics of the Banbakri antelope (*Boselaphus tragocamelus*), a species widely distributed in northern India, is lacking. The present study examined the physical and chemical properties of Banbakri dung collected from the Haryana Agricultural Farm, VKS College of Agriculture, Dumraon (Bihar), during August 2024 to July 2025. Physical parameters such as colour, size, and texture were recorded, while triplicate analyses were performed to estimate pH, electrical conductivity (EC), and nutrient composition. The dung was dark brown to black, firm, dry, and compact, resembling the pellet-like form of deer, goat, and sheep, with pellets measuring 1.0–2.0 cm in length, oval to cylindrical with rounded ends. The samples exhibited slightly alkaline pH ( $7.77 \pm 0.16$ ) and EC ( $1.29 \pm 0.07$  dS/m), indicating potential for soil enrichment. Macronutrients were calcium ( $0.61 \pm 0.078\%$ ), nitrogen ( $0.50 \pm 0.03\%$ ), phosphorus ( $0.13 \pm 0.02\%$ ), and potassium ( $0.46 \pm 0.004\%$ ), while micronutrients included zinc ( $85.00 \pm 6.21$  mg/kg), copper ( $26.00 \pm 2.94$  mg/kg), iron ( $1401.5 \pm 51.55$  mg/kg), and manganese ( $146.15 \pm 17.69$  mg/kg). This first record of Banbakri antelope dung composition indicates its potential as a nutrient-rich organic amendment for sustainable agriculture. Banbakri dung could be a potential application to improve the fertility of soil and used as fuel as well as pest deterrence.



### Article History

Received: 16 October 2025

Accepted: 26 December 2025

### Keywords

*Boselaphus tragocamelus*;  
Macronutrients;  
Micronutrients;  
Organic Fertilizer;  
Soil Fertility;  
Sustainable Agriculture.

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Doi: <http://dx.doi.org/10.12944/CWE.20.3.16>

## Introduction

Organic manure improves soil fertility, enhances soil structure, supports beneficial microbes, provides slow-release nutrients, and promotes long-term sustainable plant growth. Declining soil fertility is a critical challenge in global agriculture, including India, where mechanization, reduced cattle farming, and presently crop residue burning have accelerated nutrient depletion.<sup>1-2</sup> For marginal farmers, inorganic fertilizers are often unaffordable, leading to negative nutrient balances as essential elements are continuously removed through crop harvests. In fact, livestock manure and plant residues have been used as organic amendments to restore soil fertility, improve crop growth, and sustain soil health.<sup>3-4</sup> Organic manures also support beneficial soil microorganisms, suppress pathogens, and enhance food security.<sup>5</sup>

The *Banbakri antelope* (*Boselaphus tragocamelus*) is a key herbivore that shapes vegetation in dry Indian landscapes, but its growing population and overlap with farmlands also create human–wildlife conflict. The Banbakri (*B. tragocamelus*), an ecologically significant herbivore, occurs widely across 18 Indian states, with notable populations in Bihar.<sup>6-7</sup> Despite its ecological and potential economic value, it has received little attention in the context of agriculture. In contrast, cow dung has long been recognized in India as a multifunctional agricultural input, serving as manure, purifier, biofertilizer, pest repellent, and energy source.<sup>8-10</sup> Kusum,<sup>11</sup> documented the ranging patterns and dung-pile habitat use of Nilgai (*Boselaphus tragocamelus*), whereas Zoromski, *et al.*,<sup>12</sup> later reported the species' latrine ecology, providing valuable insights into its spatial and behavioural patterns. Banbakri dung serves as a natural fertilizer that enhances soil health and, due to its strong odour, can also deter Nilgai from crop fields, providing dual benefits of soil enrichment and pest control while aiding seed dispersal. Yet, no research has examined the potential of Banbakri (*B. tragocamelus*) dung as a soil amendment. With increasing interest in organic waste–based fertilizers as cost-effective and eco-friendly alternatives to chemical inputs,<sup>12-13</sup> exploring this underutilized resource is timely and necessary. Previous studies indicate that ruminant dung often contains essential macro and micronutrients beneficial for soil fertility.<sup>14-15</sup> Studying the physical and chemical properties of Banbakri (blue bull) dung is essential

for understanding its potential uses in agriculture, renewable energy, and ecological management.

To the best of our knowledge, this is the *first study* to document the physical characteristics and nutrient composition of *Banbakri antelope* (*Boselaphus tragocamelus*) dung. By addressing this gap, the study not only establishes baseline data on its nutrient profile but also evaluates its potential as an organic fertilizer for enhancing soil fertility, regulating soil pH, and improving soil stability. This offers a new basis for recognising Banbakri dung as a sustainable bioresource with potential applications in agriculture.

## Materials and Methods

### Study Area

The present investigation was conducted at the Haryana Agricultural Farm, Veer Kunwar Singh College of Agriculture, Dumraon, Bihar, India, from August 2024 to July 2025. The site lies at 25.533° N latitude and 84.157° E longitude and is dominated by agricultural land interspersed with natural vegetation, which provides suitable habitat and foraging grounds for free-ranging *Banbakri antelope* populations.<sup>16</sup> The region has a subtropical climate, characterized by hot summers, a monsoon season, and cool winters, supporting year-round agricultural activities.

### Sample Collection

Fresh dung samples were collected randomly from multiple sites within the farm to ensure representativeness across habitats. Both male and female *Banbakri antelope* were observed during the study period. Sampling was conducted on a monthly basis, yielding one composite dung sample per month ( $n = 12$ ); each composite consisted of approximately 10 freshly voided pellets pooled from spatially separated defecation sites and multiple individuals to minimize sampling bias. Samples were collected using sterile gloves, placed in clean, labelled polyethylene bags, and transported to the laboratory in insulated containers. On-site physical characteristics such as colour, shape, and size of pellets were recorded. Pellet dimensions were measured using a safe-seed model (brand) Vernier Calliper. Observations of dung deposition and antelope behaviour were documented using a Sony digital still camera (30× optical zoom, model DSC-WX500), and photographic evidence was used to support field records.

### Sample Preparation

Collected dung samples were air-dried at room temperature and crushed into fine powder using a laboratory grinder. The powdered samples were stored in clean, airtight containers until further analysis. The following parameters were analyzed in triplicate to determine nutrient composition: pH: determined using a calibrated digital pH meter in a 1:5 dung-to-water suspension.<sup>17</sup> Electrical Conductivity (EC): measured with a digital EC meter in a 1:5 dung-to-water suspension. Calcium (Ca), Iron (Fe), Zinc (Zn), Copper (Cu), and Manganese (Mn): Quantified using Atomic Absorption Spectrophotometry (AAS). Total Nitrogen (N): Estimated using the Kjeldahl method. Total Phosphorus (P): determined by standard spectrophotometric methods. Total Potassium (K): measured using flame photometry.<sup>18</sup>

### Data Analysis

Results were expressed as mean  $\pm$  SD (n=3). Statistical analyses and data visualization were performed using Microsoft Excel (2010). All efforts were made to minimize analytical errors.

### Results

#### Physical Characteristics of Dung

The *Banbakri antelope* (*Boselaphus tragocamelus*) is a common species in rural landscapes, providing opportunities to foster wildlife appreciation outside protected areas. Their dung consists of dense, hard pellets, resembling those of other ruminants such as deer, sheep, and goats, making it suitable for use as fuel in rural households. Field observations revealed that *Banbakri antelopes* frequently defecate at specific locations within their habitat,

forming dung latrines. Such latrine behaviour may play a role in social communication and territorial marking. The compact nature of their faeces allows limited air penetration, enabling the pellets to burn for longer durations compared to dung from cattle such as cows and buffaloes. While deer and goat pellets share similar density, they are smaller in size compared to *Banbakri antelope* droppings. Despite this, rural communities, particularly those belonging to economically disadvantaged groups, commonly utilize such dung as fuel during winter.

Morphological traits such as texture, size, shape, and colour reflect ecological adaptations of *Banbakri antelope* to semi-arid habitats and provide useful markers for non-invasive species identification. The pellets varied in texture from firm and dry to compact, depending on moisture content and diet. Dung colour ranged from dark brown to black, while the odour was mild but occasionally strong, resulting primarily from microbial decomposition of fibrous plant matter, and possibly associated with anal gland secretions. Pellet dimensions measured between 1.0 and 2.0 cm in length, with an oval to cylindrical shape resembling those of deer, sheep, and goats. These characteristics reflect the animal's high-fibre herbivorous diet and adaptive digestive physiology. Notably, dung condition also provides insight into the health status of *Banbakri antelope*. Normal dry, separated pellets indicate adequate fibre intake and healthy rumen function, whereas clumped or loose droppings may suggest digestive disorders or dehydration. The physical attributes of *Banbakri antelope* dung are summarized in (Table 1).

**Table 1: A summarising measured physical characteristics of Banbakri antelope dung**

Parameter	Observation
Texture	Firm, dry, to compact pellets forms
Colour	Dark brown to black
Odor	Noticeable Odor
Shape	Pellet like elongated, oval shaped
Dry weight	Variable (depends on moisture, retained form)
Ends	Rounded
Size	1.0 to 2.0 cm in length
Nature	Dry and separated larger than goat and sheep pellets

**Chemical Composition of Dung**

Chemical analysis of *Banbakri antelope* dung revealed a nearly neutral to moderately alkaline pH,

with a mean value of  $7.77 \pm 0.16$ , and an electrical conductivity (EC) of  $1.29 \pm 0.07$  dS/m (Table 2&3).

**Table 2: Proximate nutrient composition of *Boselaphus tragocamelus* dung**

S. N.	Nutrient / Property	Concentration (approx.)	Remarks
1.	Nitrogen (N)	~0.50 %	Comparable to cattle dung (0.4–0.5%), slightly lower than goat manure (0.6–0.7%)
2.	Phosphorus (P)	~0.13 %	Improves crop phosphorus availability by reducing soil fixation
3.	Potassium (K)	Moderate level	Enhances water-use efficiency and crop resilience
4.	Calcium (Ca)	Adequate level	Contributes to soil structure and plant development
5.	Magnesium (Mg)	Present	Supports chlorophyll synthesis and enzyme activity
6.	Iron (Fe)	>1400 mg/kg	Higher than cattle dung; useful for Fe-deficient calcareous soils
7.	Zinc (Zn)	Optimal range	Important for micronutrient-deficient rain fed agroecosystems
8.	Copper (Cu)	Optimal range	Plays role in enzymatic functions and crop growth
9.	pH	Slightly alkaline	Suitable for both acidic lateritic and alkaline alluvial soils
10.	Electrical Conductivity (EC)	Moderate	Indicates safe application across diverse soil types

**Table 3: Summary statistics of macro and micro nutrient content of (*Boselaphus tragocamelus*) dung (mean  $\pm$  SD)**

Parameters	Mean	Standard deviation ( $\pm$ )	Units	Minimum	Maximum
PH	7.77	0.16	-	7.64	7.94
Electrical Conductivity (EC)	1.29	0.07	dS/m	1.21	1.36
Calcium (Ca)	0.61	0.078	%.	0.55	0.73
Nitrogen (N)	0.50	0.03	%.	0.46	0.54
Phosphorus (P)	0.13	0.02	%.	0.12	0.16
Potassium (K)	0.46	0.04	%.	0.40	0.51
Zinc (Zn)	85	6.21	mg/kg	76.00	90.00
Copper (Cu)	26	2.94	mg/kg	24.00	29.00
Iron (Fe)	1401.5	51.546	mg/kg	1326.00	1442.00
Magnesium (Mg)	146.15	17.694	mg/kg	121.00	162.30

These values indicate a favourable range for soil application, with moderate salinity levels within safe thresholds for most crops. Among macronutrients, the dung was found to contain  $0.50 \pm 0.03\%$  nitrogen (N),  $0.13 \pm 0.02\%$  phosphorus (P), and  $0.46 \pm 0.04\%$  potassium (K). Calcium (Ca) concentration was measured at  $0.61 \pm 0.078\%$ , underscoring

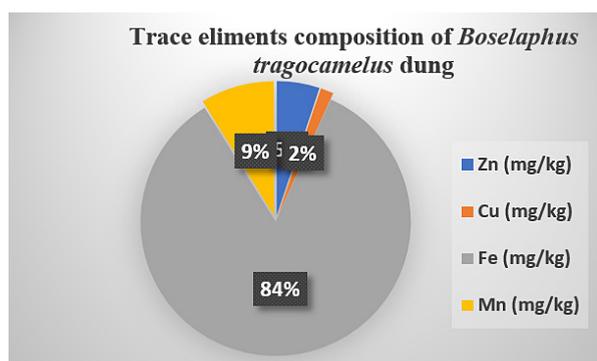
its importance in improving soil structure and plant physiological processes. Micronutrient concentrations were particularly notable. Zinc (Zn) averaged  $85 \pm 6.21$  mg/kg, copper (Cu)  $26 \pm 2.94$  mg/kg, iron (Fe)  $1401.5 \pm 51.55$  mg/kg, and manganese (Mn)  $146.15 \pm 17.69$  mg/kg. The relatively low inter-sample variability highlights a

consistent nutrient profile across dung samples. A pie chart summarizing the relative abundance of selected micronutrients (Zn, Cu, Mn, Fe) is presented in (Figures 1&2,) emphasizing the dung's potential role in nutrient cycling and soil fertility enhancement in the eastern Indo-Gangetic Plains.

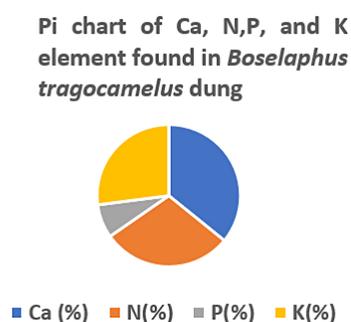
### Ecological and Agricultural Implications

The nutrient profile indicates appreciable concentrations of macro- and micronutrients (N, P, K, Ca, Fe, Zn, Cu, Mg), supporting its potential as a natural soil amendment for sustainable agriculture. It is a good source of nitrogen, phosphorus, and potassium, which slowly release to nourish plants, making it a alternative to chemical fertilizers for

sustainable agriculture farming. The observed nutrient profile suggests that *Banbakri antelope* dung may stimulate plant growth through its contribution of essential macro- and micronutrients. In particular, the presence of N, P, and K, along with high levels of Fe, Zn, Cu, and Mn, could support the synthesis of plant growth regulators such as auxins and cytokinin's, enhance root development, and improve nutrient uptake. Thus, beyond its use as a domestic fuel source, Banbakri dung holds promise as a natural soil amendment in agroecosystems. The highlighting its potential role in enhancing soil fertility and promoting sustainable agricultural practices in (Figures 1& 2).



**Fig. 1:** Pie chart showing the composition of micronutrients found in the dung of *Boselaphus tragocamelus*.



**Fig. 2:** Pie chart showing the composition of macronutrients found in the dung of *Boselaphus tragocamelus*.

### Discussion

The present study is the first to focus directly on the physical characteristics and proximate analysis of *Boselaphus tragocamelus* (*Banbakri antelope*) dung in India, with implications for soil fertility and agricultural sustainability. The pellets measured 1.0–2.0 cm in length and were oval to cylindrical, closely resembling those of deer, sheep, and goats, reflecting the species' high-fibre herbivorous diet and efficient digestive physiology. The findings show that their faecal pellets are not only a reflection of digestive physiology and health of animal but also a potential resource for sustainable rural livelihoods and agroecosystem management. Its facts, many ungulate species are recognized as vital ecosystem regulators, serving as indicators of habitat quality, protection and management levels, as well as forming an essential prey base for higher mammalian

predators.<sup>19-20</sup> Banbakri dung, essentially undigested remains of ingested plant material, reflects the ecological adaptations of this large herbivore to semi-arid environments.

### Ecological and Behavioural Relevance

Latrine behaviour observed in *Banbakri antelopes* is consistent with patterns reported in other large herbivores such as deer and antelope species, where dung deposition at fixed sites is associated with social communication and territorial marking.<sup>12-21</sup> Such behaviour may also contribute to localized nutrient hotspots in rangelands, enhancing soil fertility around latrine sites. The pellet-like morphology, with a size range of 1–2 cm, aligns with the faecal characteristics of other small to medium-sized ruminants. Variation in texture and colour is indicative of dietary fibre content and moisture

levels, which can serve as a non-invasive tool for monitoring health and habitat quality. Banbakri dung occurs as dense, hard pellets similar to those of other small ruminants (e.g., deer, sheep, and goats), a characteristic that enhances its handling efficiency and makes it particularly suitable for use as a solid biofuel in rural households. Banbakri exhibit latrine behaviour, in which individuals repeatedly defecate at specific sites, and this pattern is believed to function as a form of social communication for marking territory, conveying presence, and maintaining group cohesion. Banbakri likely use dung pellets to communicate reproductive status, more or less similar observation represented by Zorowski *et al.*,<sup>12</sup> The pelletized form, dark coloration, and dry texture of Banbakri dung demonstrate efficient water reabsorption in the hindgut, an adaptive trait of large ruminants in water-limited landscapes.<sup>22</sup> The larger pellet size compared to goats and sheep corresponds with differences in body mass and gut volume.<sup>23</sup> Such morphological traits not only support non-invasive species identification but also aid in ecological monitoring, including assessments of forage quality, habitat use, distribution, and movement patterns.<sup>24</sup> Furthermore, dung piles and latrines serve important social and territorial functions, used by dominant males and females for communication, territory marking, and escape orientation.<sup>7,25</sup>

### Fuel / Household Utility

The dense, compact structure of Banbakri dung pellets makes them suitable as an alternative biofuel in rural settings. Unlike cow or buffalo dung, which requires drying and loses energy value rapidly during burning,<sup>10</sup> Banbakri pellets allow slower combustion due to their limited porosity. This aligns them more closely with goat and deer pellets, which are traditionally used in some rural communities as a winter energy source.<sup>5</sup> Such practices highlight the unrecognized role of wild ungulates in supporting rural energy security, particularly among economically marginalized groups. However, sustained collection of dung for domestic use should be carefully balanced against its ecological role in nutrient cycling. Beyond ecological roles, the study highlights Banbakri dung as a largely underutilized resource in Indian agroecosystems. Field observations by first author in Shahabad region (Bihar) revealed its traditional uses by local people as a mosquito repellent, antifungal treatment

(“Dad khad khujli, Dinai”), and as a domestic heating fuel during winter months, consistent with reports for other ruminant dung.<sup>2-9,10</sup> A supplementary ethnographic note indicates that local communities often associate Banbakri with traditional practices, viewing the species as both a symbol of ecological harmony and, at times, an agricultural challenge, which shapes their attitudes toward its management.

### Nutrient Composition and Soil Fertility

Nutrient analysis indicated that Banbakri dung contains satisfactory concentrations of calcium, phosphorus, nitrogen, potassium, and comparatively higher levels of trace elements such as zinc, copper, and iron than cattle dung. This composition underscores its potential as an alternative to chemical fertilizers. The slightly alkaline pH and moderate EC levels suggest that it can be safely applied across diverse Indian soil types, ranging from acidic lateritic soils of eastern India to alkaline alluvial soils of the Indo-Gangetic plains.<sup>26</sup> The measured total N in our samples (0.50%) falls within the typical range reported for fresh cattle dung (~0.5–1.9%) and goat manure (~0.6–1.5%) in the literature, suggesting that the nutrient status of the dung studied is consistent with other livestock manure sources. Importantly, its nitrogen content (~0.50%) is comparable to or slightly higher than cattle manure, though lower than goat manure.<sup>27</sup> “The dung pH measured at X is higher than the neutral baseline for fresh cattle manure (~6.8) and comparable to reported goat manure pH (~7.8–8.9). SciELO+1 Elevated EC in our samples (Y dS/m) may reflect increased soluble salts, consistent with patterns observed in composted livestock manures.” The presence of these nutrients may stimulate the synthesis of plant growth hormones, promoting root growth and improving nutrient uptake. The high iron concentration (>1400 mg/kg) is particularly valuable for Fe-deficient calcareous soils in semi-arid regions such as Rajasthan and Bundelkhand.<sup>28</sup> Moreover, its zinc, copper, and magnesium content may address micronutrient deficiencies and support key physiological processes in crops.

### Conservation and Agroecosystem Implications

The role of *Banbakri antelope* in nutrient cycling outside protected areas underscores the need to view this species not merely as a crop pest but as a contributor to ecosystem services. Their dung enriches soils, supports microbial activity,

and indirectly benefits agricultural productivity. Furthermore, dung-based indicators such as pellet morphology, texture, and moisture could be developed into rapid field tools for monitoring the health and dietary condition of Banbakri populations. Ecologically, recycling wild herbivore dung contributes to nutrient cycling, soil organic matter buildup, microbial diversity enhancement, and the restoration of degraded soils, particularly in resource-constrained dryland farming systems.<sup>29-30</sup> The observed phosphorus concentration (0.13%) aligns with the role of animal manures in improving phosphorus availability through the blocking of soil adsorption sites.<sup>31</sup> In addition, dung application improves soil structure, water retention, and infiltration capacity, thereby enhancing resilience in rainfed agriculture. Comparative studies suggest that goat manure often performs better than cattle manure in boosting plant growth and soil quality,<sup>32-33</sup> yet the present results show that Banbakri dung offers comparable potential.

#### **Future Research**

Banbakri dung serves multiple functions fuel, fertilizer, ecological marker, and health indicator bridging the gap between wildlife ecology and rural livelihoods. Future research should quantify the energy value of dung pellets, assess their decomposition rates in different soil types, and compare nutrient release patterns with those of domesticated ruminants. Globally, animal manures are increasingly promoted as sustainable organic amendments in response to declining soil fertility, rising input costs, and ecological degradation.<sup>34-35</sup> In India, with nearly 67% of rice-growing soils nitrogen-deficient,<sup>36</sup> the use of alternative organic nutrient sources is particularly relevant. While cow dung has long been used for agriculture and energy, Banbakri manure remains a neglected resource despite the species' wide distribution across more than 18 Indian states.<sup>8</sup> Its nutrient profile and bioactive properties suggest applications not only as fertilizer but also for natural pest control, antifungal treatments, and as a bioenergy source.

#### **Conclusion**

This study provides the first comprehensive assessment of *Banbakri antelope* dung and indicates its potential as a natural soil amendment and alternative organic bioresource based on its nutrient composition. Nevertheless, its agronomic value

should be considered indicative rather than conclusive. Further investigations, including controlled field trials, nutrient mineralization studies, and long-term soil health assessments, are required to evaluate its effectiveness, biosafety, and optimal application rates. If substantiated, the careful utilization of this resource, supported by appropriate policies, farmer awareness, and rural enterprise development, may contribute to sustainable agricultural practices and improved wildlife–farming coexistence in India.

#### **Acknowledgement**

The authors are grateful to the Hon'ble Vice-Chancellor and the Nodal Officer (RKVY), BAU, Sabour, for their encouragement, support, and for providing necessary facilities (BAU Communication No. 2276/250921). The valuable support of Dr. Ansuman Kohli (Chairman) and Dr. Sunil Kumar (Scientist), Department of Soil Science and Agricultural Chemistry, BAU, Sabour, during sample processing and analysis is deeply acknowledged and appreciated.

#### **Funding Sources**

The Author(s) received financial support by Department of Agriculture, Government of Bihar, Vide letter no RKVY Cell-36/2023-PPM128/Agri, Patna dt. 09/11/2023 under RKVY research project for research work.

#### **Conflict of Interest**

The authors do not have any conflict of interest.

#### **Data Availability Statement**

The manuscript incorporates all datasets produced or examined throughout this research study.

#### **Ethical Statement**

This research did not involve human participants, animal subjects, or any material that requires ethical approval.

#### **Informed Consent Statement**

This study did not involve human participants, and therefore, informed consent was not required.

#### **Permission to Reproduce Material from other Sources**

Not Applicable

**Author Contributions**

- **Suday Prasad:** Conceptualization, Data collection, Methodology, Writing, and Statistical interpretation- Original Draft.
- **Anil Kumar Singh:** Visualization, supervision & Editing.
- **Paras Nath:** Supervision, Project administration.
- **C. S. Prabhakar:** Visualization, Writing – Review & Editing
- **Amit Kumar:** Writing – Review & Editing

**References**

1. Stoorvogel, J. J, Smaling, E.M.A, Janssen, B.H, Calculating soil nutrient balances in Africa at different scales. I. Supranational scale. *Nutrient Cycling in Agroecosystems* 35(3):227-235, DOI: 10.1007/BF00750641.
2. Sanchez, C, Wilkie., A.C. Bioenergy production potential from small ruminant manure. *Journal of Undergraduate Research*, 2017; 18: 3–6.
3. Mbatha, K.C, McHun, C.N, Mavengahama, S, Ntuli. N.R, Effect of poultry and goat manures on the nutrient content of Sesamum alatum leafy vegetables. *Applied Sciences*. 2021; 11(24), 11933; <https://doi.org/10.3390/app112411933>.
4. Gross, A, Glaser. B, Meta-analysis on how manure application changes soil organic carbon storage. *Sci Rep* 11, 5516 (2021). <https://doi.org/10.1038/s41598-021-82739-7>
5. Washaya. S, Washaya. D. D, Benefits, concerns and prospects of using goat manure in sub-Saharan Africa, *Pastoralism: Research, Policy and Practice*. 2023; 13;28. DOI/ 10.1186/s13570-023-00288-2.
6. Prasad, S, High Time of Pacing Nilgai Antelope (*Boselaphus tragocamelus*) into Mainstream as Community Conservation for Influencing Macroeconomics. *Asian Journal of Research in Zoology*. 2022; 5(1): 21-30. DOI: 10.9734/ajriz/2022/v5i130128
7. Prasad, S, Prabhakar, C.S, Kumar, A Nath, P, Ahmad, R, Documentation of Scent Marking With the Preorbital Gland in *Banbakri Antelope (Boselaphus tragocamelus)*. *Uttar Pradesh Journal of Zoology*, 2025; 46 (7):136-43.
8. Dhama, K., Rathore, R., Chauhan, R.S., Tomar, S. Panchgavya (Cowpathy): An overview. *International Journal of Cow Science*. 2005; 1(1): 1-15.
9. Gupta, K.K. Aneja, K. R. and Rana, D. Current status of cow dung as a bioresources for sustainable development, *Bioresources and Bioprocessing*. 2016; (3); 28. DOI 10.1186/s40643-016-0105-9,
10. Vij, S, . and Mishra, R. D. Cow Dung for sustainable development, *Ilkogretim Online - Elementary Education* 2021; 20 (4):2677-2681, doi: 10.17051/ilkonline.2021.04.306
11. Kusum. Studies on the ranging pattern and dung piles habit of Nilgai (*Boselaphus tragocamelus*) around Jodhpur, *Rajasthan, India. International Journal of Research and Analytical Reviews (IJRAR)*, 2018; 5, 555–559.
12. Zoromski, L. D. De Young, R. W., Goolsby, J. A., Foley, A. M, Ortega-S., J. A., Hewitt, D. G., Campbell, T.A, Latrine ecology of nilgai antelope., *Journal of Mammalogy*, 2022; 103(5):1194–1207, doi.org/10.1093/mammal/gyac056
13. Zhen, XF., Luo, M., Dong, HY., Li., SB., Li., MC., Kang, J., Variations of N-P-K contents in livestock and livestock manure compositing. *Applied Ecology and Environmental Research*, 2020;. 19(1):249-261.
14. Mostofa, K.M.G., Li, L. & Liu, C. Detection of tyrosine, trace metals and nutrients in cow dung: the environmental significance in soil and water environments. *Acta Geochim* 2018; (37) 632–638. doi.org/10.1007/s11631-018-0263-x
15. Awasthi, S., Chauhan, R., and Srivastava, S, The importance of beneficial and essential trace and ultratrace elements in plant nutrition, growth, and stress tolerance. *Plant Nutrition and Food Security in the Era of Climate Change*. 2022; 27-46. <https://doi.org/10.1016/B978-0-12-822916-3.00001-9>
16. Prasad S, Singh D. K., Choudhry S.K. Residential population structure and abundance of Nilgai (*Boselephus tragocamelus*, Pallas) in Bihar, India. *Current Journal of Applied Science and Technology*.

- 2020; 39(13):110-117. DOI: 10.9734/CJAST/2020/v39i1330687.
17. Tamony, A., and Basak, R. K. Reliability of a rapid soil test method for determination of soil pH. *Environment and Ecology*, 2010; 28 (B13):2125-2128.
  18. Singh, D., Chhonkar, P.K. and Dwivedi, B.S. Manual on Soil, Plant and Water Analysis. (2005); 200 Westville Publishing House, New Delhi.
  19. Chopra, G. and Rai, D. A study on the ecology of nilgai (*Boselaphus tragocamelus* Pallas) and its status as an unconventional pest of agriculture in and around Beer Sonty Reserve Forest, Haryana, India. *J. Appl. Nat. Sci.* 2009; 1 (2), 245–249.
  20. Rani, K., Babbar, B. K., Dhillon, A.K Population ecology and herd dynamics of Blue bull *Boselaphus tragocamelus* in forest and agrarian lands of district Ludhiana Punjab. *Scientific Reports*, 2025;15:24005 | doi.org/10.1038/s41598-025-08623-w
  21. Perez-Arteaga A, Vazquez GS Presence of free-ranging Nilgai *Boselaphus tragocamelus* (Artiodactyl: Bovidae) In Nelevo Leon, Mexico. *The southwestern Naturalist* 2020; 64(2): 145-149. DOI:10.1894/0038-4909-64-2-145.
  22. Sharma, D., Mehta, N. Digestive adaptations of arid zone ungulates: An overview. *Arid Ecosystem Studies*, 2016;. 21(1), 87–95.
  23. Kumar, S., Saini, R. Comparative analysis of dung morphology among domestic and wild ruminants. *Journal of Wildlife Monitoring*, 2018;. 12(3), 151–158.
  24. Patel, V., Sharma, R., Singh, A. Role of faecal traits in non-invasive monitoring of wild ungulates. *Indian Journal of Ecology*, 2020; 47(2), 403–409.
  25. Zoromski L.D. Social behavior and movement ecology of nilgai antelope. Master's thesis, Texas A&M University–Kingsville, Kingsville, Texas, USA (2019).
  26. Rai, D., Singh, B., & Tripathi, R. pH and EC dynamics of organic manures in eastern India. *Environmental Ecology*, 2019;37(1), 102–108.
  27. Kumar, A., Sharma, P., Verma, S. Micronutrient deficiencies and management strategies in Indian soils. *Journal of Soil and Water Conservation*, 2020; 19(1), 33–40.
  28. Yadav, A., Mandal, R. Use of goat and cattle manure in enhancing soil fertility and crop yield. *International Journal of Sustainable Agriculture*, 2017; 9(4), 89–95.
  29. Singh, J., Kumar, V., Meena, R. Comparative nutrient profiling of cattle, buffalo, and goat manure under arid conditions. *Journal of Arid Agriculture*, 2018; 54(2), 67–72.
  30. Prakash, M., Rathi, S., & Yadav, K. (2022). Soil fertility restoration through organic amendments in semi-arid tropics. *Indian Journal of Agronomy*, 67(3), 245–252.
  31. Gichangi, E.M., Mnkeni, P.N.S., Brookes. P.C. Goat manure application improves phosphate fertilizer effectiveness through enhanced biological cycling of phosphorus. *Soil Science and Plant Nutrition*, 2010; 56: 853–860.
  32. Maerere, A., Kimbi, G. Nonga, D. Comparative effectiveness of animal manures on soil chemical properties, yield and root growth of Amaranthus (*Amaranthus cruentus* L.). *African Journal of Science, Technology*, 2009; 1: 14–21. doi. org/ 10. 4314/ ajst. v1i4. 44623.
  33. Ndung'u, M., Ngatia, L.W., R.N. Onwonga, M.W. Mucheru-Muna, R. Fu, D.N. Moriasi, and K.F. Ngetich. The influence of organic and inorganic nutrient inputs on soil organic carbon functional groups content and maize yields. *Heliyon* 2021; 7. doi. org/ 10. 1016/j. heliy on. 2021. e07881
  34. Ansah, K.O., C. Antwi, E.L.K. Osafo, S. Enning, H. Adu-Dapaah. Manure characteristics of small ruminants fed agro by-products in the guinea savannah agroecological zone of Ghana. *Ghana Journal of Agriculture Science*, 2019; 54: 67–76.
  35. Orgiazzi, A. Briones. M. J. I. Manure management and soil biodiversity: Towards more sustainable food systems in the EU 194. 2021;.doi.org/ 10. 1016/j. agsy. 2021. 103251
  36. Shekara, B. G., Venkatesh, M. Goviddappa, M., Agronomic efficiency of nitrogen as influenced by levels and time of nitrogen application in aerobic rice (*Oryza sativa*). *Environment and Ecology*, 2010; 26 (30): 2120-2122.